Metamorphosis of the Shell in the California Sea Hare, *Aplysia californica* Cooper

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DESPITE ATTEMPTS by Carazzi (1905), Mazzarelli (1893), Saunders and Poole (1910), and the present writer, the metamorphosis of *Aplysia* has not yet been observed, nor has it been possible to follow through the changes in the shell which take place as the animal metamorphoses from a planktonic veliger to a sluglike sea hare. This is because the veliger shell is lost sometime during metamorphosis so that the evidence of metamorphosis in the animal becomes obscured. In one case only has the writer seen a small outmoded veliger shell hanging in place by a very thin membrane in the apexial concavity of a very young specimen from a new species obtained from the Gulf of California.

However, the neaplysiids which are known only from the west coast of North America are distinct in that they possess a special attachment plate extending from the inner apexial area. This plate contains the built-in veliger and the metamorphic shell. This is best seen in young shells, as older animals tend to strengthen their shells by overlaying with added shell material.

MATERIALS AND METHODS

The shells of *Aplysia californica* Cooper, two to five inches in length, were procured from newly sacrificed young animals. The shells were preserved in 70 per cent alcohol. Study was done under a dissecting microscope.

EXPERIMENTAL DATA

The position of the metamorphic shell is indicated in Figure 1. The portion of this shell outline which normally comprises the veliger shell at hatching may be approximated by comparing the shell of laboratory incubated egg strings at the time of hatching with the inner areas of the shell nucleus. Size measurements are helpful in determining the areas involved in the prehatching shell. The size of the veliger from top of the hood is approximately 150 μ.

The angle of the hood in relation to the base of the shell at the time of hatching (Fig. 2), compared to the corresponding dimension in the shell nucleus, indicates the approximate starting point of free-living existence. The end of the pelagic period probably occurred at the time of the first major change in shell character in the area built after the initiation of free-living existence.

In many specimens the shell built between the time of hatching and this supposed end of the pelagic period is of slightly different color. It is a less transparent yellow and has fine growth lines, perhaps reflecting the change from the prehatching yolk food to the food that may have been available to it in the free-swimming state.

An examination of the veliger shell (Fig. 2) shows that the tendency to build a spiral shell is already indicated at time of hatching by the asymmetrically thickened edge of the initial spire. The tendency to spiral rapidly increases during the early postveliger existence. The writer believes that this is a crawling stage in which the snail's foot has taken over the locomotion for which it was not yet prepared at the time of hatching. This early stage, though very different from the adult, is probably very gastropodlike, with the animal crawling on its foot and feeding upon microscopic algal forms but retracting within its spiral shell which it closes with its operculum. This constitutes the first stage of metamorphosis.

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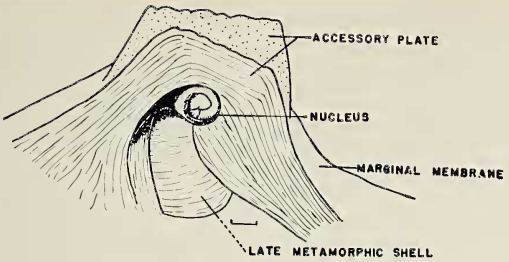

FIG. 1. Nuclear area of a shell of *Aplysia californica* Cooper showing the stages of development from the microscopic free swimming veliger to the adult plan of shell construction. The measure indicates 150 μ.

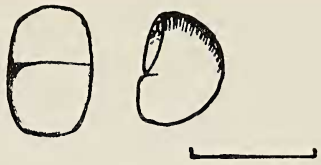

FIG. 2. Two views of newly hatched veliger larva. The measure indicates 150 μ.

As the shell completes its first convolution, it starts an even more marked tendency to flare out and flatten to form a covering over the animal rather than a house into which it may retract. At the end of the first whorl this tendency has become dominant, and by the end of the further half whorl the shell has opened out into a spoon-shaped covering which is indicated as the late metamorphic shell in Figure 1. Mazzarelli (1893) pictured a metamorphic animal which is probably a somewhat later form than this, carrying its outgrown shell on its back. During the metamorphosis, additional material is laid down on the shell, in which process the nucleus is probably first a point of muscle attachment. However, in *A. californica* an auxiliary plate is soon formed, paralleling the curvature of the intermediate metamorphic shell, which, along with later modifications, forms a new post-metamorphic plan of growth. This neaplysiid plate forms on a plane with the embryonic nucleus and becomes an extension of it.

The entire outline of the shell is modified after metamorphosis, the original larval shell being used only as a building block in the future adult shell. These shell changes are indicated in Figure 1 by the lines of growth.

SUMMARY

1. The shell nucleus, containing the veliger shell, is present in adults of *Aplysia californica* Cooper as a building block in the auxiliary plate characteristic of this subgenus.

2. The metamorphic forms of the shell are clearly preserved.

3. The implications of this shell metamorphosis are (a) a short swimming stage, (b) an intermediate, gastropodlike crawling stage in which the shell is a place of retreat, (c) a metamorphic stage with a spoon-shaped shell by which the animal is covered, and (d) a late metamorphic stage in which the animal outgrows the shell, which becomes vestigeal in the adult animal.

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